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E1F FKA F204

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GB 2258674 A

(58) Field of Search
UK CL (Edition M) E1F FKA FKF
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(54) **Inflatable well packer**

(57) An inflatable well packer includes several annular layers 1, 3, 5, 7 of material, consisting of a series of oriented fibres encapsulated in a resin. The fibres are orientated in directions relative to the direction of the circumference of the annular layers 1, 3, 5, 7 such that pressure from the bore through the annular layers causes changes to the orientations of the fibres, thus causing inflation of the well packer.

The fibres in each layer are arranged along a helices with alternating layers being wound in opposite directions. When the packer is deflated the fibres have varying pitch angles (Fig 9), the ends of the fibres extending at the lock-up angle with intermediate portions at shallower angles. When the packer is inflated the extra length of the fibres extend at the lock-up angle.

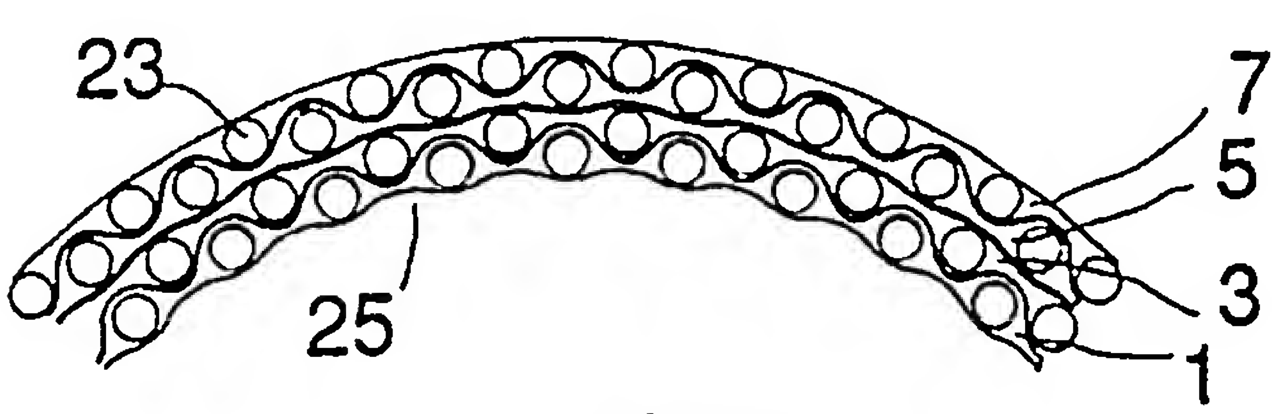

Fig 3

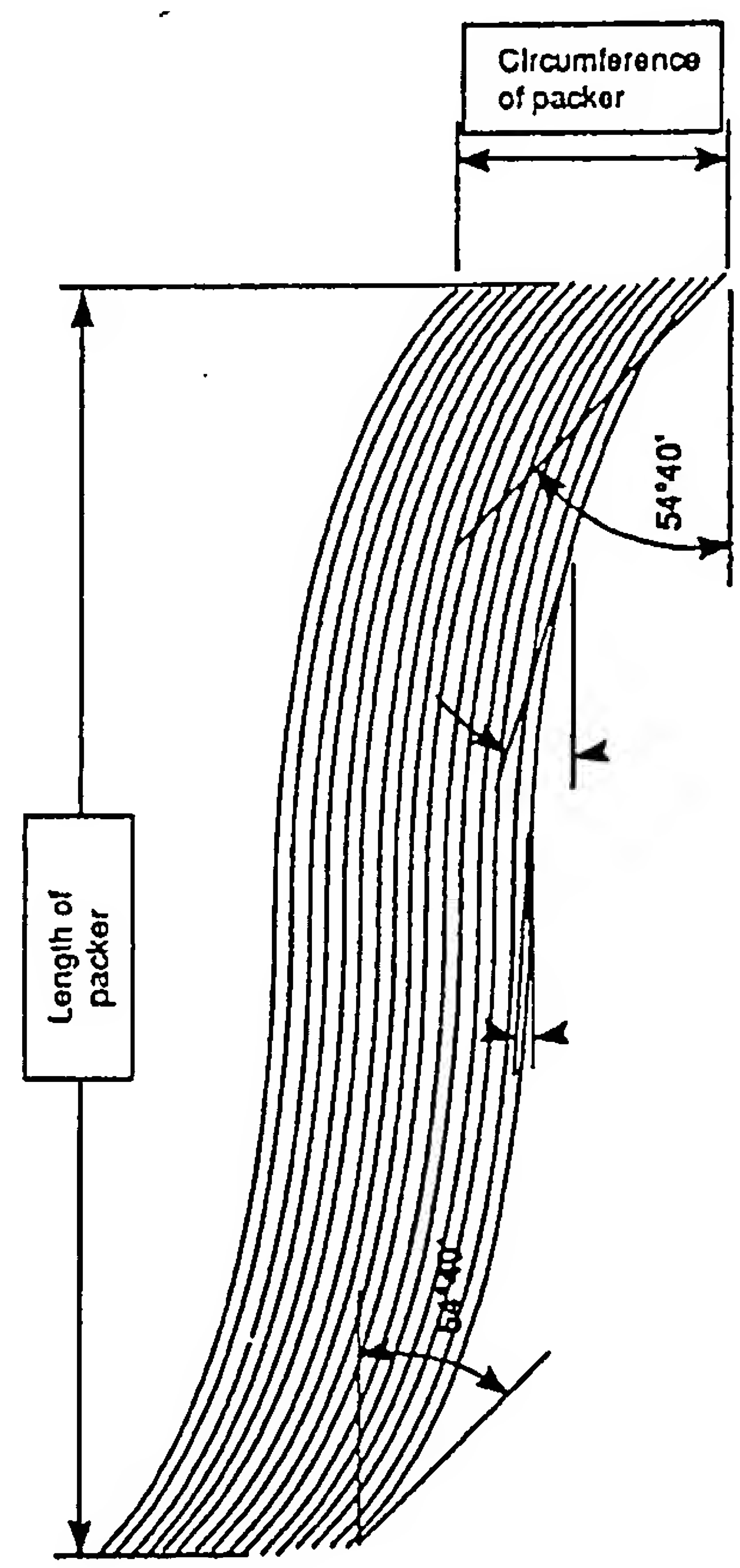

Fig 9

At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

This print takes account of replacement documents submitted after the date of filing to enable the application to comply with the formal requirements of the Patents Rules 1990.

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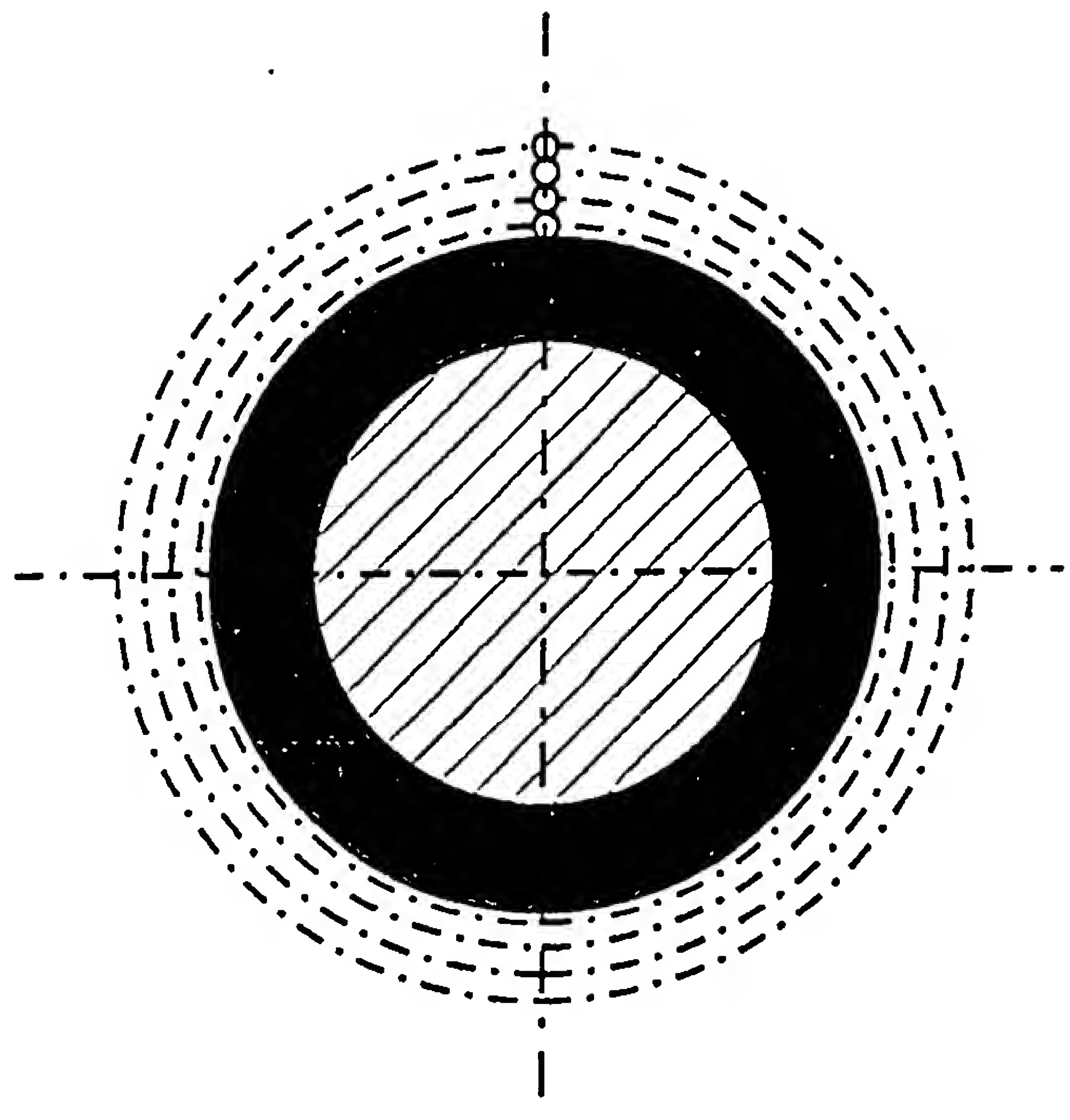

Fig 1

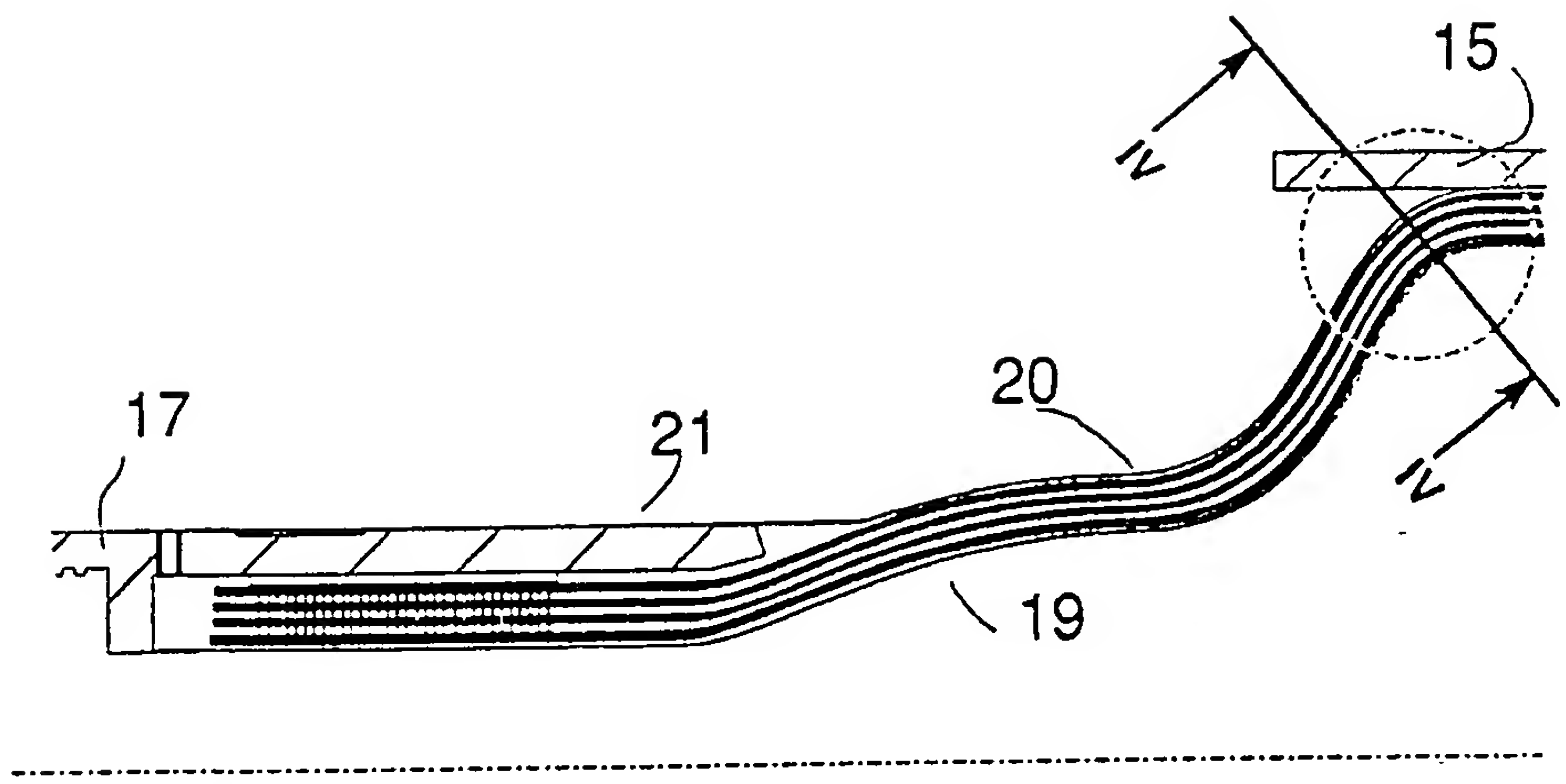

Fig 2

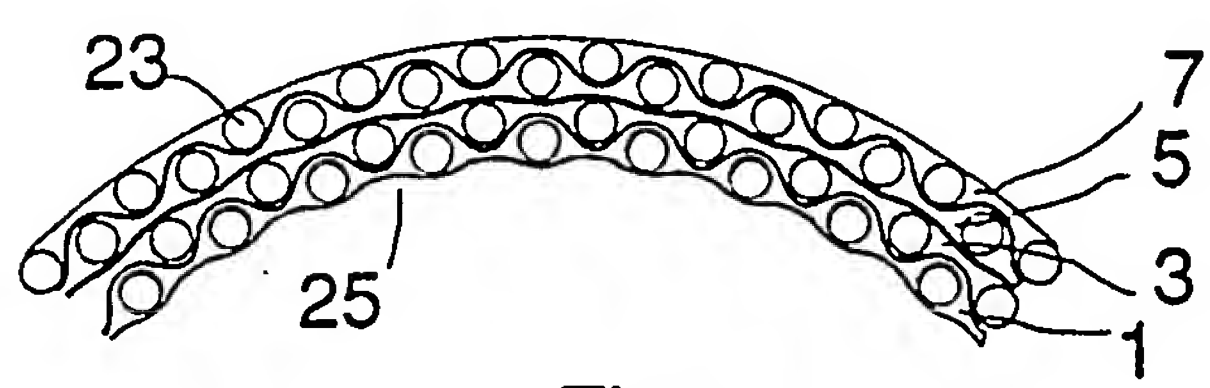

Fig 3

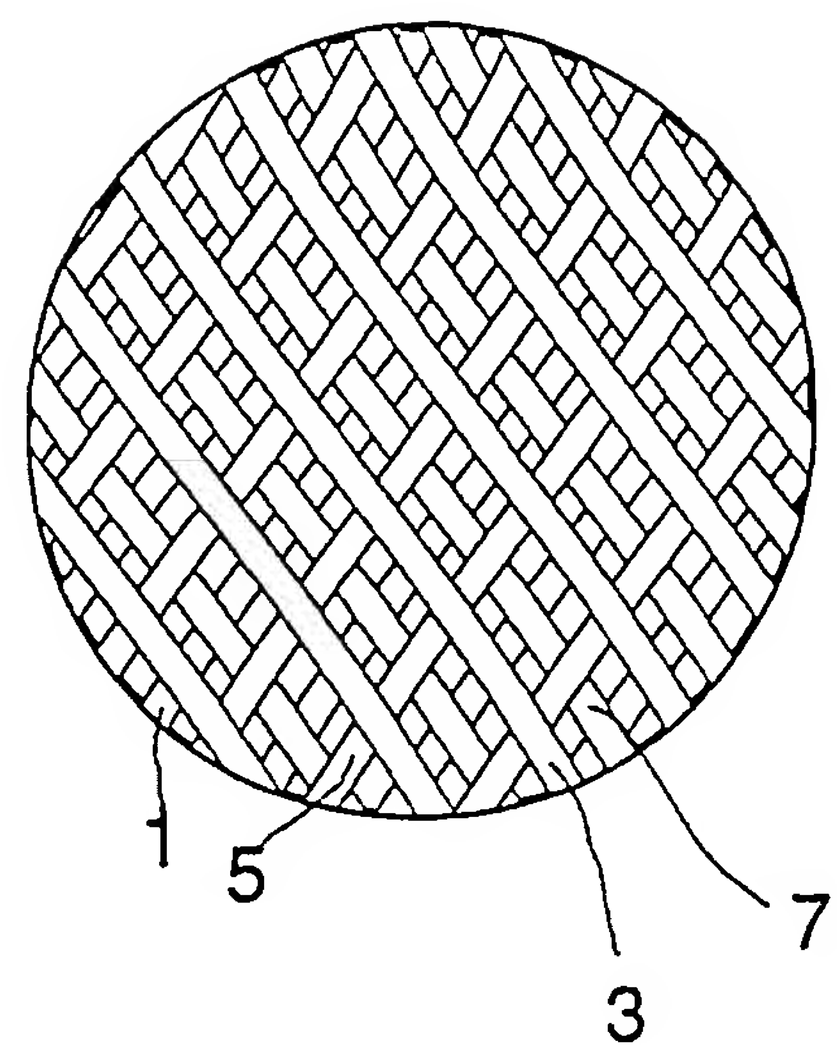

Fig 4

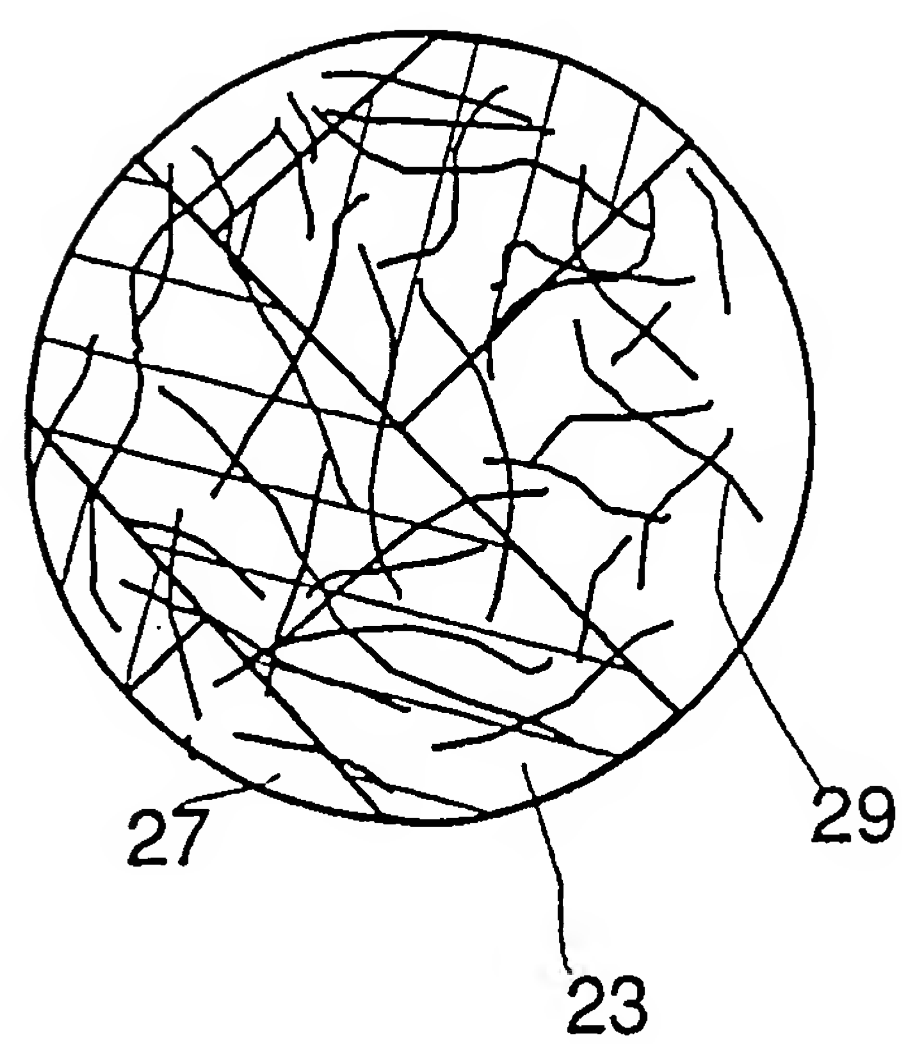

Fig 5

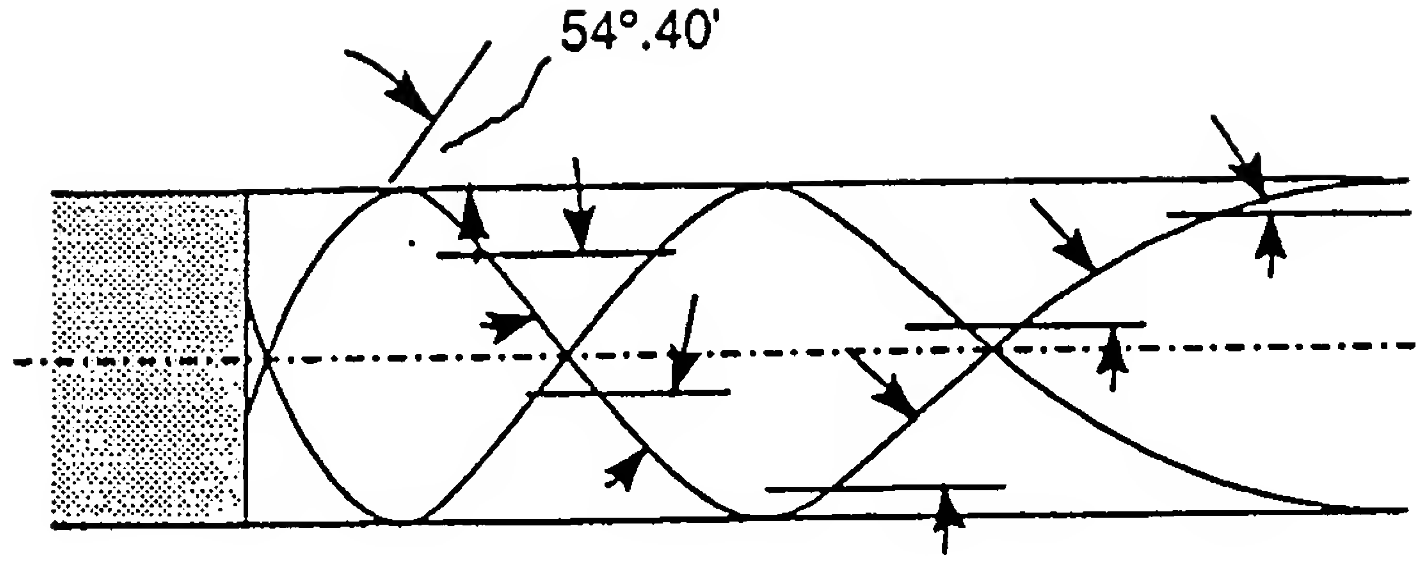

Fig 6

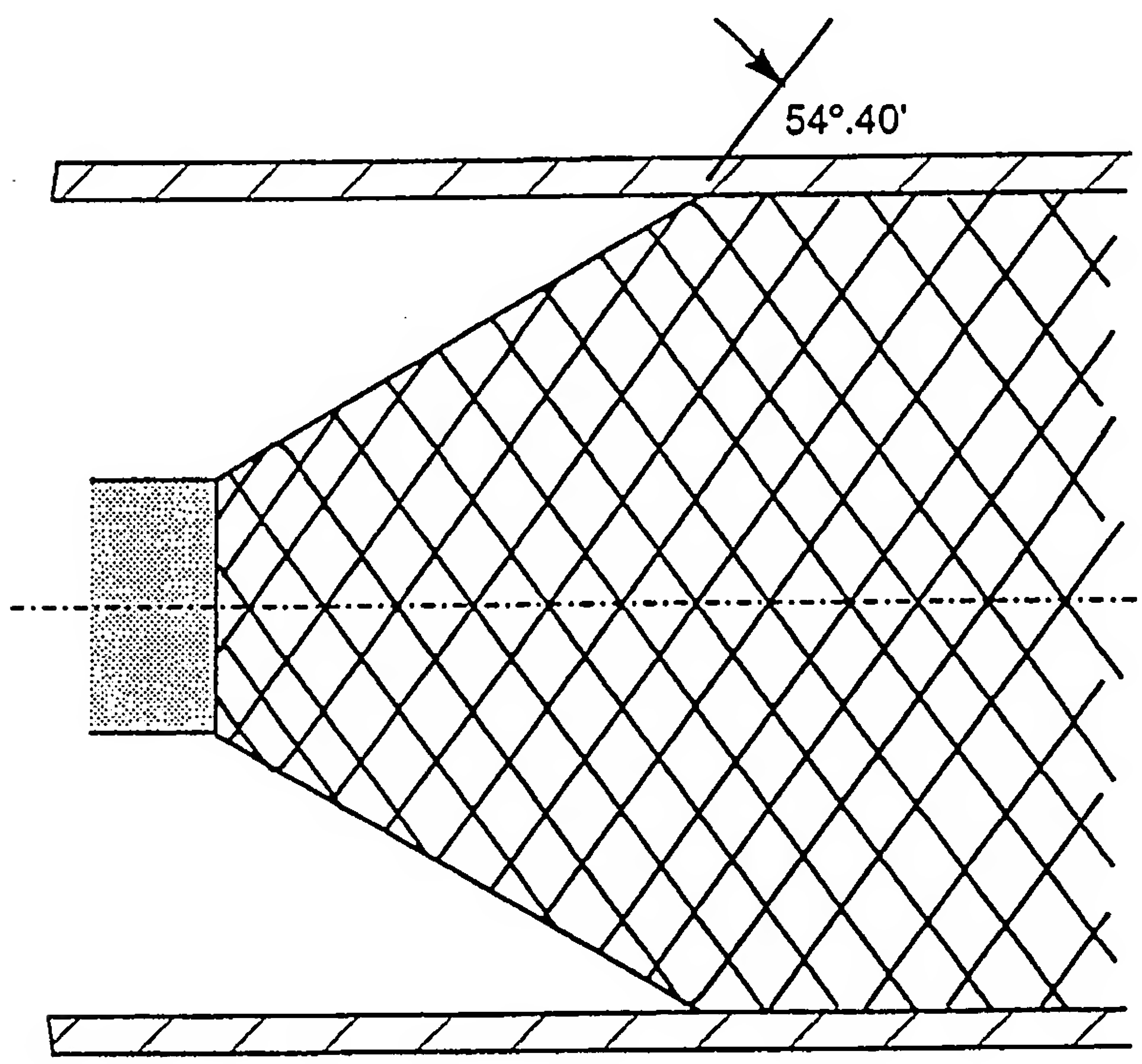

Fig 7

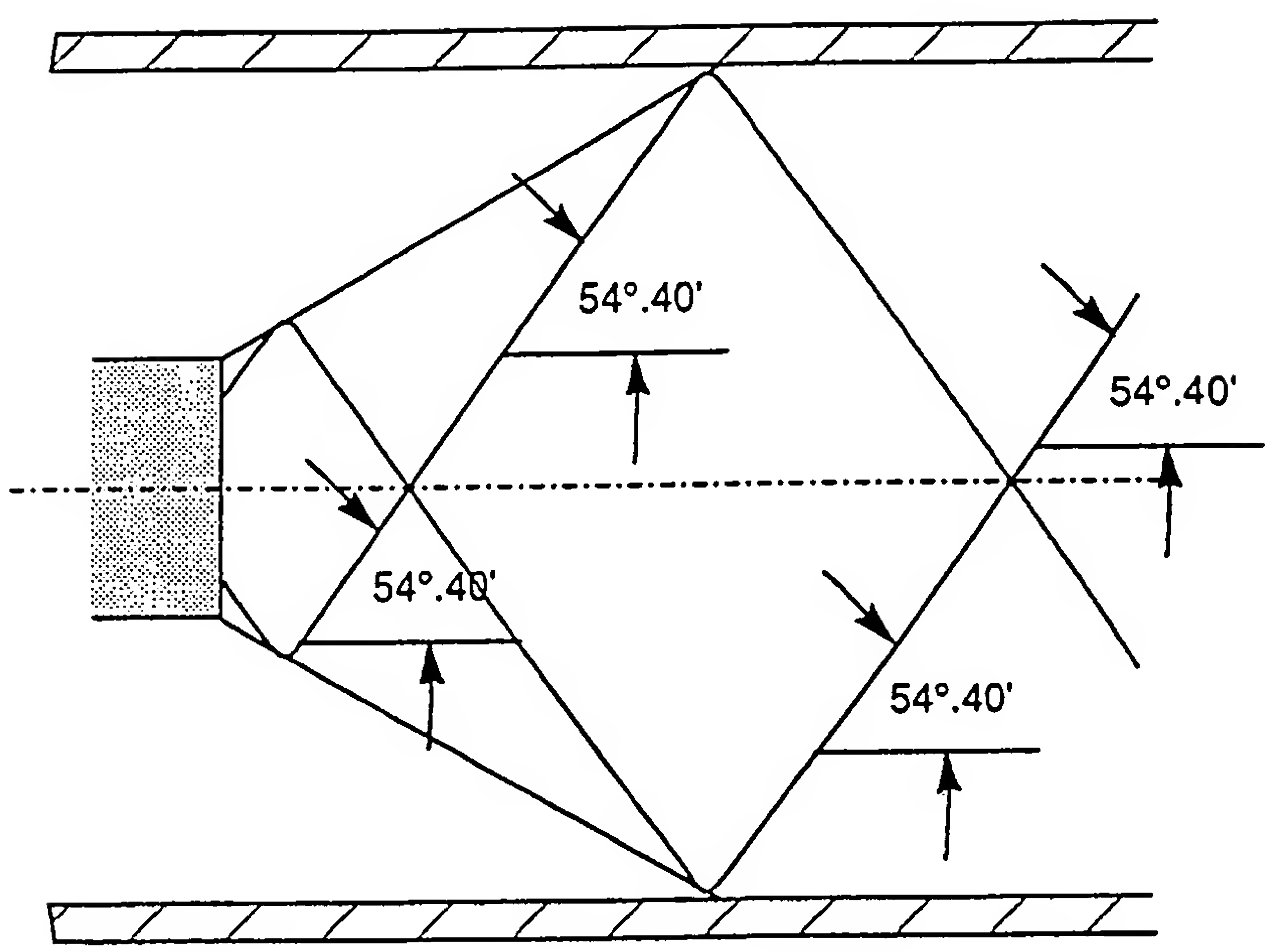

Fig 8

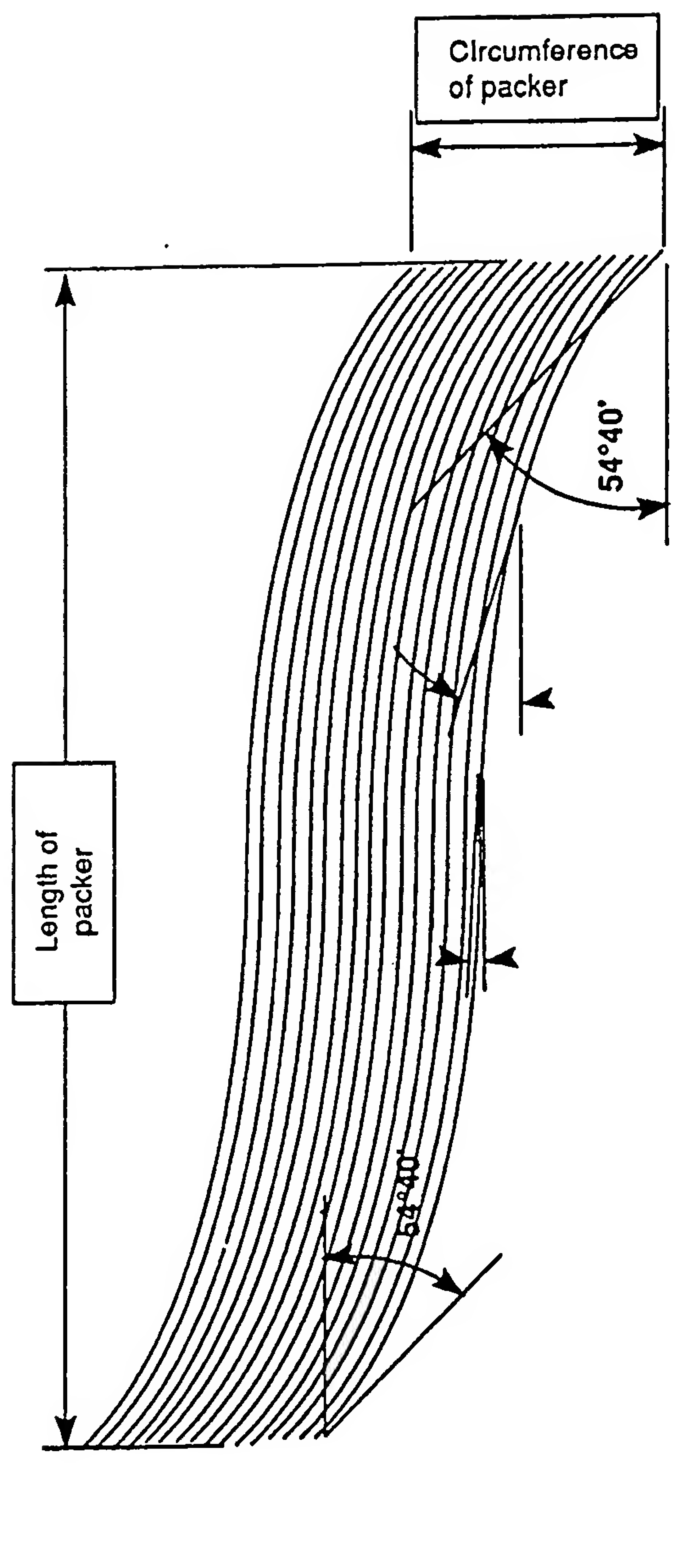

Fig 9

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WELL PACKER

This invention relates to well packers. In particular, the invention relates to inflatable well packers, which in use are inflated by fluid under pressure to isolate a zone in a well.

Inflatable well packers have been known for many years, the packers being used to isolate a zone in a well, so as, for example to enable a drill stem test to be performed, to perform a selective chemical treatment, or to isolate a redundant Zone in a productive well. There are presently two types of inflatable well packers, each being of a multi-layered construction including an elastomeric inner bladder, but varying in the bearing system incorporated in the packer. The first type of known well packer includes wire or textile fibres, woven together with their ends secured to end fittings by an epoxy potting process, the sheath of woven wire or fibres being covered in an outer elastomeric boot which will form a hydraulic seal to the casing, or open-hole surface of a wall which the well packer will, in use, isolate. The other type of inflatable well packer utilises long, peripherally overlapping strips of spring steel which, when the packer is inflated, slide radially against each other like Venetian blinds, the strips surrounding the elastomeric inner bladder. The central portions of the strips are bonded to an outer annular elastomeric boot which acts as a hydraulic seal to the casing or open-hole surface in use of the well packer. An example of a well packer of this type is shown in U.S. Patent Number 3160211.

With either of these known well packers there are a number of shortcomings. Firstly, the manufacture of either of these well packers is labour intensive. In the case of the woven sheath reinforced well packer, the reinforcing wire or fabric has to be hand-woven during assembly of the well packer. In the case of the spring steel strip reinforced well packer, the large number of overlapping strips are difficult to assemble and engage in their end fittings.

Furthermore, in either of the known types of well packers, the elastomeric inner bladder has to expand typically by twice the amount that the outer elastomeric boot has to expand. Thus if the packer has to be inflated by a ratio of 3:1 in order for the outer boot to make the required seal, the inner elastomeric bladder will have to expand by a ratio of 6:1. This results in the inner elastomeric bladder in its inflated state being very thin, thus making the inner elastomeric bladder susceptible to any micro faults which it may have in its structure. Furthermore, the high expansion ratio required by the inner elastomeric bladder severely limits the choice of materials which may be used. As a result of the limited choice of materials, the inner elastomeric bladder tends to have a very limited chemical resistance to any fluid other than water, thus limiting the life of the packer when the packer is exposed to fluids such as acids, solvents, diesel oil, and surfactants, these all being chemicals which are commonly required for treatments of zones within wells.

With regard to the outer elastomeric boot in either of the known types of well packers, although this typically only has to expand by a ratio of 3:1, and thus an

increased choice of materials enables it to have a better chemical resistance to the fluids used in the wells than that of the inner elastomeric bladder, the outer elastomeric boot still has a relatively short life span.

Finally, there is a further drawback to such known inflatable well packers, in that when they are expanded they exert a high radial stress on the end fitting as they try to expand to a diameter greater than the diameter of the end fitting. This puts a complex compressive stress on the outer reinforcing members of either type of well packer, and furthermore, exerts a high tensile stress on the reinforcing members inner surface. In some cases this has resulted in a splitting of the end fitting, this then releasing the well packer into the well bore.

It is an object of the present invention to provide a well packer, wherein these problems are at least alleviated.

According to a first aspect of the present invention there is provided an inflatable well packer comprising at least one annular layer of material wherein at least a portion of the layer of material comprises fibres which are orientated at various angles such that when is in the inflated state at least a portion of the fibres are orientated at the lock up angle, being 54° 40'.

Thus, in such a well packer the need for an elastomeric inner bladder and an outer elastomeric boot can be avoided. Furthermore the corrugations enable the differential radial stress present in known well packers

to be at least reduced relative to the equivalent expansion ratios of known inflatable well packers.

Preferably the layer(s) of material comprise a series of fibres encapsulated in a resin. The resin encapsulates the fibres on the inside and outside. The thickness of resin is preferably greater on the inside of the fibres compared to the outside.

It is advantageous for the angle of orientation of the fibres with respect to the length of the layer to vary along the length of the layer.

It is also preferable, for there to be a plurality of layers. Where there are a plurality of layers, at least a portion of the fibres within each layer are suitably oriented along the length of the layer such that adjacent layers comprise fibres which are wound in opposite directions. It is also preferable for adjacent layers to comprise fibres which are wound at different angles.

According to the invention the angles of orientation of the fibres are such that when the packer is inflated, fibres in adjacent layers will lock up so as to oppose further expansion.

The edges of the layers will usually be clamped by a respective end fitting. In such a case, preferably the fibres in the regions of the layers adjacent to the end fittings will be orientated at angles close to or the same as the lock up angle so little or no expansion is permitted at that point.

An embodiment of a well packer in accordance the

invention, together with a method of making the well packer, will now be described, by way of example only, with reference to the accompanying figures, in which:-

Figure 1 shows a cross-section of the well packer in accordance with an embodiment of the invention;

Figure 2 shows a schematic side view of part of the well packer in the region of the end fitting in the inflated state.

Figure 3 shows a schematic cross section on an expanded scale along the line IV-IV of the reinforcing fibres shown in figure 2.

Figure 4 shows a plan view in detail of the reinforcing fibres of Figure 3, the view being shown on an enlarged scale;

Figure 5 shows an enlarged view of a part of the reinforcing fibres of Figure 4;

Figure 6 shows a schematic view of the orientation of the fibres near the end fitting.

Figure 7 shows a schematic view showing the formation of the lock up angles.

Figure 8 is a detailed view of the formation of the lock up angles of figure 7.

Figure 9 shows the orientation of the fibres along the length of the packer before inflation of the packer.

Referring firstly to Figure 1, the first well packer in accordance with an embodiment of the invention to be described comprises four concentric reinforcing fibre layers 1,3,5,7 encapsulated in an elastomeric resin 9. The edges of the layers 1,3,5,7 are secured by respective end fittings, shown in Figure 2.

The term fibres includes any longitudinally orientated elements which can be comprised of any suitable material which exhibits the required strength in the longitudinal direction. This includes for example carbon or glass fibres and also steel wire type fibres.

The fibres for each of the layers are variably oriented along the length of the packer such that their orientations when the packer is inflated describe a helix, with the orientations of the fibres in adjacent layers 1,3,5,7 being in opposite senses. At each of these shoulder portions 19,20, the fibres within each layer 1,3,5,7 are oriented in their fully extended position or lock up position in the inflated state. This thus avoids the differential stresses which occur in the prior art well packers.

Before proceeding to describe the proposed packers of the invention, it is necessary to demonstrate the properties of armoured rubber hoses reinforced with plies of helically disposed wires or fibres.

Referring to the packer of figure 1 comprising two plies of helically-wound steel cables. The radius of the

cylinder is r (thickness neglected). In both plies the cables form the same angle δ with the generatrices of the cylinder but in one ply they follow right-handed helices and in the other, left-handed helices. Assuming that the length (h) of the cylinder is such that the helices are just one pitch long so that:

$$h = \frac{2\pi r}{\tan\delta}$$

With the ends of the cylinder closed and the pressure within increased, if δ is small or nil, the cylinder will tend to grow in diameter and reduce in length; whereas if δ is close to 90°, it will tend to grow in length and reduce in diameter. In both cases the volume inside the cylinder increases, but the bases of the cylinder do not tend to twist because of the balancing action of the two symmetrical plies. For a certain value of δ the cylinder will neither swell nor lengthen when inflated because any pressure change would not increase its volume. The value of this angle is calculated as follows:

The volume v of the cylinder is:

$$v = \pi r^2 \times \frac{2\pi r}{\tan\delta} = 2\pi^2 \times \frac{r^3}{\tan\delta} \qquad (1)$$

The length L of the cable is as follows:

$$L^2 = 4\pi^2 r^2 \times \left(1 + \frac{1}{\tan 2\delta}\right) = \frac{4\pi^2 \times r^2}{\sin^2\delta} \qquad (2)$$

As the cables are essentially inextensible any change in the length must be zero, so.

$$dL = 4\pi^2 r^2 \times \frac{rdr}{\sin^2\delta} - 4\pi^2 \times \frac{r2\cos\delta}{\sin^3\delta} = 0$$

which leads to: $$\frac{dr}{r} = \frac{d\delta}{\tan\delta} \qquad (3)$$

The volume change as a function of radius and angle δ is:

$$dV = 2\pi^2 \left(\frac{3r^2 dr}{\tan\delta} - \frac{r^3 d\delta}{\sin^2\delta} \right)$$

and dV will be zero if:

$$\frac{3dr}{\tan\delta} = \frac{rd\delta}{\sin^2\delta} \qquad \text{or} \qquad \frac{dr}{r} = \frac{d\delta}{3\cos\delta\sin\delta} \qquad (4)$$

Equations (3) and (4) are simultaneously satisfied for one value δ_0 of δ.

$$\frac{1}{\tan\delta_0} = \frac{1}{3\cos\delta_0\sin\delta_0}$$

hence:

$$3\cos^2\delta_0 = 1$$

$$\cos\delta_0 = \frac{1}{\sqrt{3}}$$

or $$\tan\delta_0 = \sqrt{2}$$

It can therefore be concluded that the ideal value of the helix angle for no expansion or swelling of the reinforced packer is $\delta = \delta_0 = 54° \ 40'$.

Where the helix angles of a set of helically oriented fibres are oppositely directed to the fibres in an adjacent layer, and the fibres in the adjacent layers are at the lock-up angle of 54° 40', if internal pressure is applied to the layers, then the fibres within the two layers will lock-up preventing further expansion.

Thus in the well packer of the present invention, a large radial tensile stress is prevented at the entrance 21 to the end fitting 17 as would be the case in conventional well packers. In the well packer, the fibres are variably oriented along the length of the packer in the packers uninflated state. Thus, as the packer is inflated the fibres will try to change their helical angle relative to the longitudinal axis of the packer up to the maximum angle of 54° 40', at which point the fibres in adjacent layers will lock up. In order to reduce the expansion of the layers close to the end fittings 17, the initial helix angle before expansion of the well packer is arranged to be at least 54° 40', so that the packer does not expand by a large amount before the interaction of the adjacent layers causes locking up.

Figures 6 to 9 show that as the distance of the fibres from the end fittings 17 increases, the fibre helix angle is reduced such that the amount by which the fibres can be displaced is increased, thus causing a corresponding expansion of the packer. Thus control of the orientation of the fibres along the length of the packer provides a corresponding control of the amount which the various regions of the packer can expand, the inflated expansion profile having a uniform stress distribution.

The composition of the layers 1,3,5,7 is shown in more detail in figures 3, 4 and 5. Referring firstly particularly to Figure 3, when the well packer expands, the fibres 23 within each of the layers 1,3,5,7 move away from each other, causing necking of the inner circumferential surface of the well packer as a result, as indicated at 25 in Figure 3, the outer surface of the packer being constrained into a cylindrical configuration by the lining 15 of the steel casing.

Referring to figure 6 in particular it can be seen that as the packer is inflated the layers expand. This occurs fist at the end fitting where the fibres are already close to the lock up angle. As the pressure increases subsequent fibres further away from the end fitting orientate themselves further until they reach the lock up angle. This process continues until the desired extent of inflation is reached and/or until the lock up angles are achieved for essentially all the fibres along the length of the packer.

It will be appreciated that the more layers of fibres incorporated within the well packer, the finer will be the resulting mesh distribution, and the less will be the unsupported regions 27 shown in figure 5, between the fibres 23. In order to reduce the number of unsupported regions 27 which may occur, it may be advantageous to include short fibre reinforcements 29 in the elastomeric matrix as indicated in Figure 6. When the well packer is inflated, these short fibres 29 will maintain the links between the fibres 23, thus providing a bridging action over the unsupported regions 27 when the well packer is expanded. Suitable materials for the fibres 29 include glass fibres and short Kevlar fibres. The fibres 29 will

also perform a memory function, helping the well packer to recover to its non-inflated form after inflation.

Fibres in adjacent layers can vary in the angle of orientation to the length of the packer as well as having a varying angle of orientation within each layer.

It will be appreciated that whilst in each of the embodiments of the well packer described here before by way of example, there are four layers of reinforcing fibres, a well packer in accordance with the invention may have any number of layers, including a single layer, although multiple layers are advantageous. Where a single layer of reinforcing fibres is used, the fibres have to be bi-directionally interlaid at a varying orientation so that the interlocking function can be achieved in the single layer and in addition the use of the short fibres 29 to bridge the gaps between the reinforcing fibres, when the well packer is in an expanded state, is particularly advantageous.

It will also be appreciated that whilst in the particular well packers in accordance with embodiments of the invention, described hereinbefore, the encapsulating resin is an elastomeric material, a well packer in accordance with the invention enables the use of encapsulation resins other than elastomeric, thus allowing the selection of highly resilient material with good resistance to the well bore and treatment fluids. Suitable alternative encapsulation resins are fluoroplastics such as PTFE or FEP, which are sold under the trade names Teflon and Xynar, or polyphenylene sulphide such as PPS, which is sold under the trade names

Ryton and SUPEC. All of these materials have limited elastic properties, but do have good chemical resistance of the chemical, pressure, and temperature conditions in which the well packer is likely to be required to operate. Where a non-elastomeric material is chosen for the encapsulating resin, the use of the short reinforcing fibres 29 to provide a memory function to help recovery of the well packer to its non-inflated state is particularly advantageous.

CLAIMS

1. An inflatable packer, which is capable of being inflated to form a seal when in the desired position and deflated for removal from said position, comprising at least one annular layer of material, in that at least a portion of the layer of material comprises fibres encapsulated in an elastomer resin, wherein said fibres are orientated in the form of a helix, the angle of the helix being such that when the packer is in the inflated state the angle of the helix is equivalent to the lock up angle being 54° 40′.

2. An inflatable packer according to claim 1, characterised in that the thickness of resin encapsulating the fibres on the inside is greater that the thickness of the resin on the outside of the fibres.

3. An inflatable packer according to claim 1, characterised in that it comprises more than one layer.

4. An inflatable packer according to claim 3, characterised in that each layer is separated by a suitable separating means.

5. An inflatable packer according to claim 4, characterised in that the separating means is made from polytetrafluoroethylene.

6. An inflatable packer according to claim 3, characterised in that the layers are not separate but are formed from a common encapsulating material.

7. An inflatable packer according to claim 1, characterised in that at least a portion of the fibres within each layer are orientated along the length of the layer in a helical manner.

8. An inflatable packer according claim 1, characterised in that the angle of orientation of the fibres with respect to the direction of the length of the layer varies along the length of the layer.

9. An inflatable packer according to claim 3, characterised in that adjacent layers comprise fibres which are wound in opposite directions.

10. An inflatable packer according to claim 3, characterised in that adjacent layers comprise fibres which are wound at different angles to the direction of the length of the layers.

Patents Act 1977 Examiner's report to the Comptroller under Section 17 (The Search report) -15-	Application number GB 9303099.7
Relevant Technical Fields (i) UK Cl (Ed.M) E1F (FKA, FKF) (ii) Int Cl (Ed.5) E21B	Search Examiner D J HARRISON Date of completion of Search 4 MAY 1994
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Documents considered relevant following a search in respect of Claims :- 1 to 10

Categories of documents

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P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages	Relevant to claim(s)
X,P	GB 2258674 A (HEAD) 17 FEBRUARY 1993 see particularly Figures 3-6 and pages 7,8	1 to 10

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